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# Historical review of demand side management in China: Management content, operation mode, results assessment and relative incentives

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ABSTRACT

Traditional power load management in China is featured by power rationing without considering user demand. However, since the 1990s, demand side management (DSM) has been introduced by local governments and enterprises in China to improve terminal power efficiency and optimize resources allocation, and certain breakthrough have already been achieved. Demand response aims at improving the energy efficiency of end-users and achieving emission reduction targets. Based on the development status of power industry and electricity market in China, this paper firstly reviews the three key development stages of traditional DSM, including management content, operation mode and results assessment. Secondly, this paper analyzes the demand side management aimed at energy conservation and emissions reduction, selecting the core elements and key processes influencing terminal power efficiency of DSM development. In addition, DSM safeguard system and incentive mechanism, including political, economic, technical and managerial measures, are further discussed to achieve the aim of energy conservation and emission reduction. Finally, this paper systematically analyzes related policies and regulations proposed by the government, and put forward relative policy recommendations for DSM development in China.



**Contents**



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## 1. Introduction

The two energy crises and the declining environment in the 1970s stimulated developed countries to adjust their energy strategies accordingly. The most striking among these strategies was to include energy conservation and environmental protection in long-term state policy goals. More specifically, demand side management (DSM), which is known as an effective way to achieve sustainable development, was proposed [1,2]. Currently, it is acknowledged that DSM involves power consumption activities that can effectively guide users to optimize their power consumption modes, improve terminal power efficiency, optimize resource allocation and protect the environment [3,4].

With DSM, the existing management functions can better meet the requirements of market economic system. It fundamentally changes the traditional thinking mode, which simply focused on suppliers to increase resource supply to meet demand growth, and also establishes a new concept of transforming energy saved by the demand side into an alternative energy of the supplier [5]. Untimely, it can achieve the purpose of providing the same energy service in a most economic way with maximum social benefits [2]. Demand side management (DSM) is indicated to take effective measures to guide users to optimize the power consumption mode, improve the terminal power efficiency, optimize resource allocation, improve and protect the environment, and do electricity management with minimum cost [6,7]. DSM is an innovation of the traditional power management mode, and plays an important role in the optimization of power resources allocation.

DSM was introduced into China at the beginning of the 1990s, before which traditional load management had been focused on power rationing during peak periods. Generally, the development of DSM programs in China can be divided into three stages: DSM before the Electric Power System Reform (1991–2002), DSM after the Electric Power System Reform (2002–2005) and DSM centering on energy conservation and emission reduction (the eleventh five-year-plan period (2005–2010) and the 12th five-year-plan period (2010–2015)) [8,9]. This paper discusses the management content, operation mode, implementation subjects and results assessment at each key stage of DSM development and proposes a DSM management mechanism aimed at achieving the emissions reduction targets during the 12th five-year-plan period, including management content, safeguard system, incentive mechanism, operation mode and results assessment. Finally, the relevant incentives concerning the DSM programs are discussed, mainly includes policies and regulations, as well as relative recommendations. This is the novelty of the paper, and the study will provide reference for policy-maker in the near future.

## 2. Traditional demand side management (1991–2002)

### 2.1. Traditional power load management

In the 1970, owing to the tight power supply, it was typical to have multiple days of power rationing per week and to have peak averting measures implemented several times per day [10]. However, when such measures were implemented, users could not receive financial compensation, which was unreasonable and unfair because when electricity demand surpassed supply and the power industry effectively held monopoly status, it was the power consumers who were the aggrieved. In the 1990s, although the power supply situation had been gradually improving, the main method of load management at this stage was still power rationing without considering the needs of users.

#### 2.1.1. Management content

In the traditionally structured power industry in China, the load management program is an important instrument for the power groups to reduce investment on peak-load capacity and to postpone investment in network upgrades [11]. The load management program includes the direct-load-control project, the load-adjustment project, the peak-load pricing project, and the time of use (TOU) project. Note that peak-load pricing and the TOU program, which functioned as a load management tool before the reform of the electricity market, are still important tools for the realization of DSM after the reform, but they are essentially different approaches. The former is a type of load management tool for the monopolizing power groups, and in this way, the consumers are forced to accept it without the right to choose; the latter is regarded as an effective mechanism for load shifting, and consumers are free to accept or reject its implementation.

#### 2.1.2. Implementation subjects

The implementing subject of load management was the former State Power Corporation, which held a monopoly [12]. The former State Power Corporation achieved the goals of shifting peak load, smoothing load curve and establishing an emergency limit load by directly monitoring the load. As the former State Power Corporation had a vertically integrated electricity supply chain and could obtain most of the economic and environmental benefits arising from the implementation of load management projects, it was inspired to implement the load management program.

#### 2.1.3. Operation mode

Load management techniques originated from the load control techniques. In the late 1970s, after consulting and tracking the international load control techniques and considering the actual situation of the country, China started to develop load control devices. During that time, the load control techniques were primarily used to solve the conflict between the rapid growth of electricity demand resulting from social development and the temporary shortage of the electricity supply. In the 1970s and 1980s, many power supply enterprises in China mainly used one-way power controllers and a two-way terminal control technique to control the consumers' electricity indicators [13,14].

*2.1.3.1. One-way power control.* This is the simplest form of control technique. One-way power control is primarily used to implement

the control function by using the control equipment installed at the user's site. The basic approach is that the supply enterprise inputs power indicators into the control equipment in advance (e.g., the maximum amount of monthly electricity consumption) and when electricity consumption meets or exceeds the indicator during the certain period (usually a month), the control equipment will output a signal to turn off the user's electricity switch. Here, the supply enterprise cannot immediately obtain the dynamic power consumption information of the users or coordinate the normal order of power utilization for all types of users according to the latest electricity data.

*2.1.3.2. Two-way load-monitoring technique.* The principal characteristic of this technique is to implement a load monitoring center and a master station of a data communication network at the power supply enterprise. In addition, monitoring devices, which have an open-loop or closed-loop control mode that is used for data communication, should also be installed at the users' site. The open-loop control mode is used to implement orders to trip or close the users' switches directly and remotely. The closed-loop control mode involves the system operator setting the power index remotely at the load management center, and according to the relevant index (power and electricity quantity) the terminal device will perform the monitoring task in an automatic control fashion, with real-time data acquisition of the load and power data. This technique has the features of limited electricity consumption without widely shedding the load in the case of a shortage of power supply and achieves orderly power utilization.

### 2.2. Demand side management before the electric power system reform

The lecture by Hammed Nezhad, an American scholar, on DSM and its application in China in 1991 marks the introduction of DSM into China [3]. Since then, the former State Planning Commission, the former State Economic and Trade Commission, the former National Science and Technology Department, the former Ministry of Power Industry, the former State Power Corporation, other large or medium-sized users, the related scientific research institutions, colleges, universities, and social groups have accomplished a significant amount of work and held various types of activities involving international communication to promote the development of DSM, such as the implementation of DSM pilots and demonstration projects, training events and communication about DSM techniques, implementing energy-saving and energy-storage technologies (e.g., compact energy saving lamps, cooling storage air conditioning technology, and regenerative electric boilers), and implementing load control techniques and green lighting demonstration projects, which have been successfully applied in Jiangsu, Shanghai, Zhejiang, Henan, Hubei, Hebei, Fuzhou, Guangzhou, Xi'an and so on [15].

**Table 1**
DSM-related activities of the former State Power Corporation [11,12,16].

| Year | Work content |
|---|---|
| 1995 | Establishment of DSM pilot projects in the grids of North China. |
| 1998 | Establishment of the DSM guidance center. |
| 1999 | Establishment of the magazine titled “Demand Side Management”. |
| 2001 | DSM became an assessment criterion for the first-class power supply enterprise. |

#### 2.2.1. Implementation subjects

DSM was first introduced into China when the Power industry had the characteristics of a vertically integrated system [16]. The government introduced DSM, which was considered as a type of regulation to the former State Power Company, into the business scope of the electric power company, which enabled DSM to influence energy efficiency management and load management. As a result, the former state power corporation became the implementation subject of DSM. The primary activities that the former state power corporation implemented to promote the use of DSM are shown in Table 1.

During that period, representatives from the former State Power Corporation have visited the USA, Canada, Western Europe and northern Europe several times to interview experts and study the relevant techniques. They learned the basic policies and measures for the promotion of DSM in foreign countries and implemented several DSM conferences at home to promote the concept of DSM.

#### 2.2.2. Operation mode

The Operation mode of DSM before the electric power system reform is shown in Fig. 1.

*2.2.2.1. Collect information for designing DSM by performing market research and market analysis.* Only through extensive market research we could obtain first-hand information about the users' needs and better understand the users as well as ourselves to enable the implementation of a scientific and rational DSM program that takes both the users' needs and the system capacity into consideration. In addition, load prediction is necessary.

*2.2.2.2. Use DSM market strategies for peak load reduction and load rate improvement.* Make segmentation on the basis of the target market and implement the marketing tasks according to the

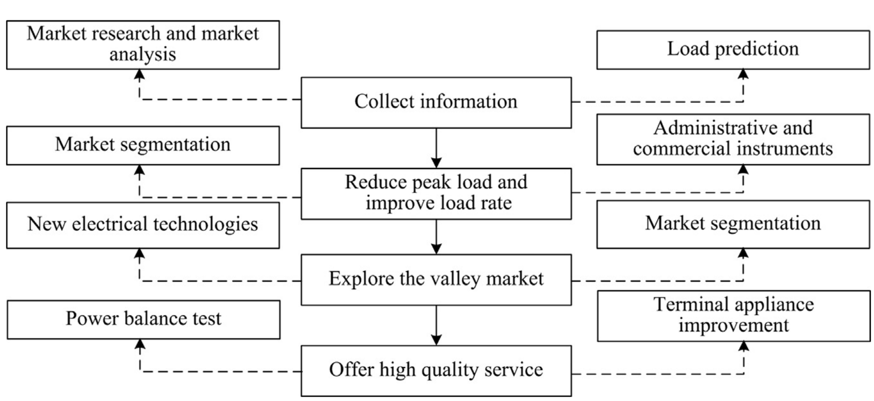



**Fig. 1.** Operation mode of DSM before the electric power system reform [5,17].

**Table 2**
Overall benefits of DSM implementation in China 1991–2002 [4,5,9,18].

| Parameters | Value |
|---|---|
| Energy saving | 130.47 TWh |
| Removed peak load | 3.8 GW |
| Coal saving | 58.6 Mt |
| $CO_2$ mitigation | 153 Mt |
| $SO_2$ mitigation | 1.33 Mt |

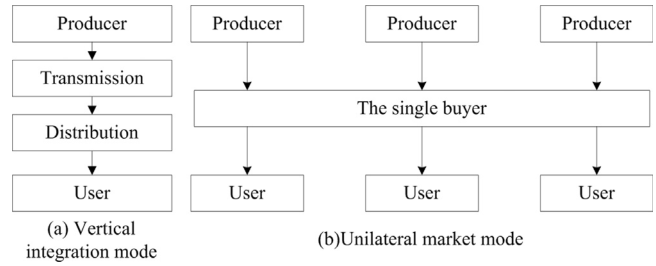



**Fig. 2.** The market modes before and after the system reform [14,15,19].

market conditions and the characteristics of the users as well as the systems. Reasonable administrative and commercial instruments are also necessary.

*2.2.2.3. Develop a new power consumption growth point and explore the valley market.* The power companies are indicated to emancipate the mind, develop the electricity market, fully utilize idle capacity and implement new electrical technologies, such as storage air conditioning and household electric water heaters.

*2.2.2.4. Strengthen DSM to offer high-quality services.* Load managers gradually bear the duty of testing the power balance for power units, helping users analyze the consumption structure and production processes, and assisting users to improve the terminal power-consuming equipment.

### 2.2.3. Results assessment

Table 2 shows the overall benefits of DSM implementation when it was initially introduced in China (1991–2000). Table 2 shows that the DSM programs between 1991 and 2000 have significantly benefited China. As much as 130.47 TWh of energy and 58.6 Mt of coal have been saved and 3.8 GW of peak load explain shortly how the averted peak load has been measured [4,5]. The environmental benefits were also considerable, which include reductions of 153 Mt in $CO_2$ emissions and 1.33 Mt in $SO_2$ emissions. Large- and medium-sized electricity consumers, such as metallurgy, petrochemical, building materials, chemicals, textiles, machinery and pharmaceutical industries, are the main objects of DSM. Energy-saving lamps, frequency control devices, high-efficiency motors and reactive-compensation products and technologies have been widely used. Shengli Oil Field, Daqing Oil Field, Capital Iron and Steel Company, Nanjing Iron and Steel Company and other large companies are very active in developing DSM pilot projects and have achieved considerable economic benefits [18].

DSM at this stage had the characteristic of strengthening load management while paying little attention to the improvement of energy efficiency. Regarding the managing measures, administrative orders are primarily used by power groups for load shifting and power rationing, with economic measures, technical means and induction methods used only as auxiliary methods. This type of management approach is precisely contrary to the approach DSM is meant to take. DSM values the initiative and the voluntary rather than forced involvement of the end users, and administrative orders should only be used during periods when electricity is in short supply. With the acceleration of electricity industry marketization, DSM needs to change to provide an important contribution to the healthy and sustainable development of the electricity industry [19].

## 2.3. Demand side management after the electric power system reform (2002–2005)

In 2002, the State Council officially approved the Electricity Reform Program, which was introduced to break the monopoly and introduce competition, improve efficiency, reduce costs and improve the price mechanism, optimize resource allocation, promote the development of the electricity industry and the national network, and build the government-supervised market system of separating administrative functions from enterprise management, thereby ensuring fair competition and healthy development [20]. Subsequently, the former State Power Corporation was split and restructured, resulting in five national generation groups and two national grid companies. Simultaneously, the Electricity Regulatory Commission was established for the supervision and control of the industry, which changed the regulation mechanism of regulating groups [10]. All of the above actions signaled the beginning of the Electric Power System Reform, as shown is Fig. 2, whereby the Power Sector was transferred from the old vertically integrated mode to the single-buyer mode [11].

### 2.3.1. Management content

The reconstruction of the electric power industry has changed the vertically integrated management system of the power groups. The sub-operation mode is used, and the competition mechanism is introduced. Market-oriented reform in the power industry has directly influenced DSM by removing the requirement of incentives for its implementation. These factors will provide new challenges to the implementation subjects of DSM. However, electricity production has a characteristic of instantaneous equilibrium. The grid is the intermediary that connects the generation enterprises to the customers and is also the material basis for implementing DSM. Therefore, as a state-owned key enterprise that is related to the country's energy security and national economy, the state grid is still the implementing subject of DSM. The state grid has taken many administrative, economic, and technical measures, including peak load shifting and peak load aversion management [15,20].

DSM at this stage mainly included energy efficiency management, load management, and orderly power utilization management.

*Energy efficiency management* is achieved through the end users' adoption of advanced technologies and efficient equipment to improve the terminal power efficiency, reduce power consumption and save costs while simultaneously achieving electricity and energy reduction and reducing pollutant emissions.

*Load management* is implemented through the use of load shaping technology to improve the users' power consumption mode and reduce the maximum load on the grid. That is, taking measures such as averting peak load to save electricity, reduce or postpone the need to install additional capacity, improve the overall system efficiency and achieve the goals of energy saving and environment protection [21].

*Orderly power utilization management* is used when the supply and the demand are significantly mismatched. That is, to use administrative, economic, technical and other means to ensure the supply to a user while also limiting power use of other users, which results in a rational allocation of resources and a balance between supply and demand, and through which the goals of maintaining social order and minimizing the shortage of power can be achieved.

#### 2.3.2. Management mode

As the implementation subject of DSM in China, grid corporations have taken many measures which mainly include peak load shifting and peak load averting management. Administrative, economic, technical and other measures have been used [22,23].

*2.3.2.1. Administrative measures.* Those mainly include adjusting customers' production shifts, staggering working hours and arranging electric equipments maintenance during peak season or peak hours. To make full preparation, local governments and the grid corporations choose the enterprises and the equipment, set the time and the capacity in accordance with the principle of shifting peak load first, then averting the peak load, then limiting the use of power and finally shedding the load.

*2.3.2.2. Economic measures.* The mostly used economic measure is price policy such as the TOU price, the season-of-use price and interruptible price, which guide users consuming electricity during valley hours while avoiding consumption during peak hours. Economic measures also include providing concessional loan or financial subsidies for the purchase of energy-efficient equipments.

*2.3.2.3. Technical measures.* The State Grid Corporation has performed research on electric vehicle application, and some have made advantages of the Beijing Olympic Games and Shanghai World Expo to promote the commercial operation of electric vehicle. Research on the application of the heat pump has also been done. The State Grid has made a promotion plan for heat pump implementation and taken four provinces including Liaoning as pilots to build different kinds of heat pump technology demonstration projects. The State Grid also works to construct efficiency power plant and promote the use of energy storage technology, high efficiency motor, VVVF technology, green lighting technology and energy-efficient and energy-saving products, building a platform for companies and users and actively providing customers with energy advice and services to promote energy conservation.

*2.3.2.4. Other measures.* The State Grid Corporation has always attached great importance to DSM, taking the leading role in DSM work and constantly improving the DSM system and mechanism. DSM has been included into its performance assessment standard and been considered as one of its marketing strategic objectives. It has strengthened the system construction and introduced more than 1300 regulations such as regulations on the grid's loss of power and implementation plan of DSM in the State Grid Corporation. It has made clearly the direction and measures of DSM. The State Grid Corporation also works hard on the training, advocacy and external communication of DSM. Besides, it has also promoted DSM policies, techniques and application experience in multilevels through street propaganda, the journal named Demand Side Management, website, catalogs etc, which successfully made DSM a social consensus and duty.

#### 2.3.3. Implementation process

Fig. 3 shows the plan and implementation process of DSM during this period.

(1) *Set the objectives of DSM planning*: This step could refer to the external operating environment of the grid corporation, the needs and interests of the users and its characteristics and power supply task. The objectives of DSM mainly include

**Table 3**
Overall benefits of DSM in China 2003–2005 [5,8,14].

| Year | Electricity shortage (GW) | Peak load reduction (GW) | Coal conservation (Mt) |
|---|---|---|---|
| 2003 | 24 | 9 | 5.6 |
| 2004 | 30 | 11 | 6.7 |
| 2005 | 32 | 13 | 7.2 |

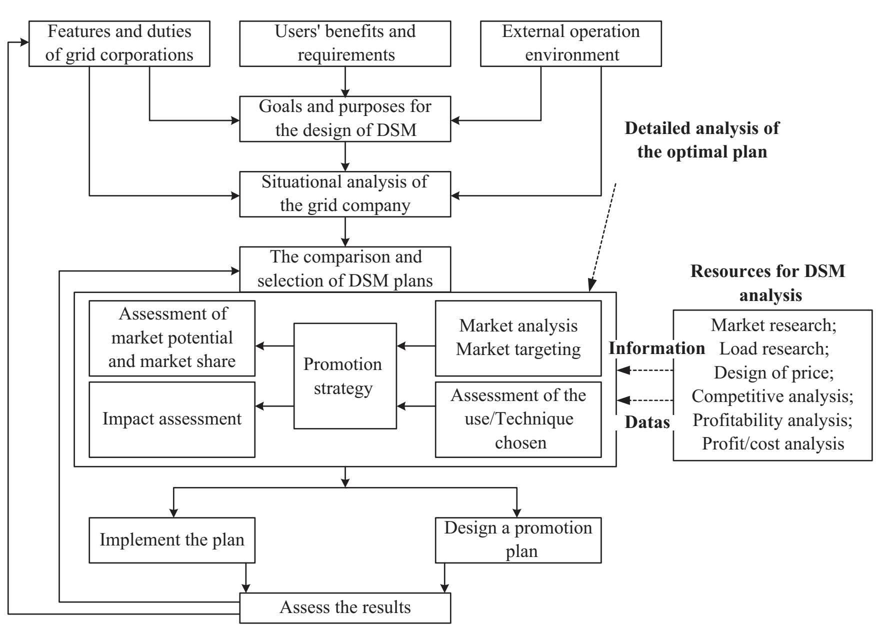



**Fig. 3.** The plan and implementation process of DSM [4,5,13,23].

**Table 4**
Peak load reductions for selected provinces in 2003 [14–18,24].

| Province | Peak load reduction (MW) |
|---|---|
| Jiangsu | 2800 |
| Shanghai | 1700 |
| Hubei | 1000 |
| Hebei | 250 |
| Zhejiang | 1400 |
| Guangdong | 2250 |
| Hunan | 700 |
| Total | 10,100 |

increasing power conservation and energy conservation and saving operating expenses and facilities construction fees.

(2) *Scenario analysis*: After data collection, a literature investigation and expert consultation, implement a scenario analysis for the proposed DSM planning schemes, and determine the initial DSM portfolio.
(3) *Assess and select the schemes*: That is, sort the priority queue of all of the optional DSM schemes for selection according to the scenario analysis, the Grid Corporation's goals and the existing standards.
(4) *Perform a detailed analysis of the selected prior schemes*: This step includes the assessment of the main content, the market segmentation scheme, the technical scheme evaluation, market penetration, cost, benefit and impact.
(5) *Implementation and supervision*: Implement the optimal scheme and supervise and assess the results. Revise the DSM's objectives according to the results and make adjustments on the project portfolio and implementation scale.

#### 2.3.4. Results assessment

In the 21st century, with the sustained and rapid growth of China's national economy, the supply of electricity is in an unprecedentedly tense situation, especially during 2003–2005 when over half of all of the provinces had to implement power rationing measures because of the gap between power supply and demand [2,24]. The amount of supply shortage in some provinces and cities was over 1/3 of their maximum load. The inadequate supply of electricity had become a bottleneck that seriously hampered local economic development. However, the overall situation indicated that the shortage is seasonal and structural. Peak load, especially air conditioning load in summer, increases quickly but only lasts for a short period of time. In contrast, power consumption during valley hours is insufficient. As a result, the consumption gap between the peak and valley periods is widened. Therefore, there exists a paradox that electricity is in short supply while the utilization rate of the power system is simultaneously decreasing.

Facing this tense power supply situation, the State Grid Corporation system, in accordance with the principle of "shifting peak load first, then avoiding, and then limiting power consumption, and finally shedding the load", developed an orderly power utilization scheme for reasonable peak load shifting and peak load aversion, refinements to the capacity and period of time for enterprise and equipment, and a change from the passive power brownouts to active load shifting. The results are shown in Tables 3 and 4.

In short, DSM is playing a positive role as an important means to adjust the grid load and optimize the power consumption mode in such a tense situation where energy efficiency is not emphasized and electricity is in short supply. DSM has been used in the most severe power shortage period to avert most peak load situations and has ensured the safe and stable operation of the grid and the stability of the society.

## 3. Demand side management aimed at energy conservation and emissions reduction (2005–)

On August 31, 2011, the State Council promulgated "*The Integrated Program For Energy Saving during the 12th five-year-plan period*". According to China's 12th Five-Year Plan, non-fossil fuel generation should account for 11.4% and 20% of the total primary energy consumption by 2015 and 2020 respectively [25]. The program requires deepening the price reform of resource products and understanding the relationship among the prices of coal, electricity, oil, gas, water, mineral and other resource products. The program also advocates implementing a multistep price for living electricity and living water. According to the program, the TOU price policy should be improved and all regions must intensify the efforts on the implementation of discriminatory prices and punitive prices in accordance with state regulations. The program also requires the strict implementation of a desulphurization price and research on a de-nitrification tariff policy for coal-fuelled power plants. In addition, the program emphasizes the development of supporting policies and the orderly use of electricity, and it proposes to implement comprehensive pilot programs in cities and to promote the energy efficiency of power plants. DSM can be implemented effectively with all of these measures.

### 3.1. Management content

An organization system with clear responsibility and effective operation contributes significantly to achieving resource conservation, environmental protection, social benefits and the lowest electric service costs. DSM participants include the government, grid corporations, energy saving service companies, construction companies and consumers. In China, competition has been introduced into the generation side, while the transmission, distribution and retail sale sides are still monopolized. Hence, an organization system in which governments are leaders, grid corporations act as the primary implementing subjects, energy

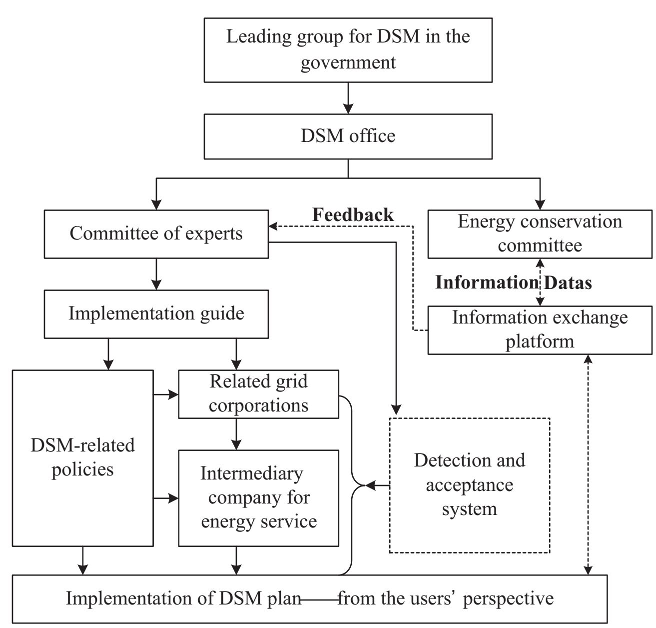



**Fig. 4.** DSM organization system [6,25,26].

saving service companies function as backbones and consumers participate actively will be established (Fig. 4).

From Fig. 4, a government-led group of DSM is established and supported by the DSM office including staff from the government, power corporations and the State Electricity Regulatory Commission. Furthermore, a committee of experts and an energy conservation committee are established under the DSM office. The former mainly consists of DSM experts and has the responsibility of implementing the relevant laws and policies to motivate grid corporations to perform DSM programs and of selecting, supervising, and testing the DSM programs. The latter mainly includes medium and large energy service companies and a governmental energy conservation center and is responsible for providing an interactive information platform for the committee of experts. A DSM program can be implemented smoothly under the joint efforts of all participants.

## 3.2. Safeguard system

A security system concerning both policy and regulation and capital and techniques are implemented to promote DSM.

### 3.2.1. Policies and regulations

A good policy environment is required to promote DSM programs and to achieve energy conservation and emissions reduction [27]. First, specific regulations concerning DSM programs are needed and all governmental departments and grid corporations are planning to include DSM resources into the electric power industry development planning, energy development planning and regional economic development planning. Second, DSM is continuously optimized by performing user energy audits, strictly checking electrical equipment energy efficiency standards, establishing DSM supervision mechanisms and formulating an after-DSM assessment system. Third, the relevant supporting policies are necessary.

### 3.2.2. Capital support

A DSM-specific fund is of great importance for the sustainable development of DSM programs. First, the government could take a fraction (0.2–0.4%) of the annual added value of the fiscal revenue to provide long-term and stable financial support for DSM programs. Second, grid corporations can list the costs of DSM (0.5–1‰) into the supply costs and consider them as a DSM-specific fund, which is indicated to be supervised and audited regularly [3,26]. Third, a DSM-specific fund is supposed to operate by providing subsidies and low-interest loans or stepping into capital markets, forming a closed-loop capital flow management.

### 3.2.3. Technology support

The upgrade of DSM techniques and products is the key point for improving the energy conservation and emissions reduction results of DSM. Government and grid corporations are relied on to take various measures to support the research, production and sales of DSM products as well as promote innovative DSM technologies. First, government departments are supposed to develop and promote various DSM measures, especially on renewable energy programs. Subsidies or rewards from a DSM-specific fund can be used to motivate grid corporations to invest in DSM technologies, especially advanced industrial technologies, energy saving technologies and new energy technologies. Second, grid corporations are working on building load management systems and DSM management information systems.

### 3.2.4. Supervision mechanism

The standardised operation and continuous optimization of DSM call for a reasonable supervision mechanism with a specialised group to provide a comprehensive and effective assessment on DSM. First, we are to develop the decision-making mechanism and accountability system of DSM programs by establishing a DSM supervisory group. Second, the DSM supervisory group may establish a DSM platform for information exchange with power users and regularly disclose the situation of the DSM programs. Third, the DSM supervisory group is intending to establish an evaluation panel of experts for the DSM projects to objectively assess the DSM program, provide feedback information and regularly summarize the assessment work.

## 3.3. Incentive mechanism

Regarding severe energy shortage and environmental pollution, we account for China's specific situations to promote DSM programs and achieve their energy saving effect. Incentive measures are very helpful.

When establishing an effective incentive mechanism, the government are indicated to focus on fiscal, tax and price policies. For fiscal and tax policies, the government first clarifies the sources for the DSM-specific funds and formulate capital management regulations to overcome the difficulty in financing DSM programs. Additionally, the government strongly advocates energy conservation. In the long run, reducing the income tax of enterprises that implement DSM and allowing the enterprises to offset the income tax using investment on professional energy saving equipment is proposed. For the price policy, the government plans to invest what is received from the implementation of discriminatory prices on energy savings and gradually abolish the preferential price of all of the high energy-consuming industries in a short time. The medium- and long-term policy is relied on to gradually increase the price level and abolish all cross subsidies

**Table 5**
Incentive mechanisms for DSM [2,6–9,28].

| Work areas | Measures | | |
|---|---|---|---|
| | **Details** | **In the near future** | **In the long term** |
| An effective incentive mechanism | Financial & tax policies | Draft and improve the DSM approach and establish the DSM special fund | Reduce or offset the income tax for enterprises implementing DSM |
| | Price policies | Use discriminatory price to encourage energy conservation and abolish preferential price for high energy-consuming industries | Abolish all cross subsidies and establish a reasonable price system |
| Various inducing measures | Technological means | Build limited value and standard of energy efficiency | Establish the efficiency standard ahead of time |
| | Administrative means | Orderly power utilization | Expand the energy-saving monitoring net |
| | Inducing means | Advertising and training | Advertising and training |

and then establish a reasonable price system that reflects the scarcity of resources. Meanwhile, the government may use advertising to encourage the entire community to actively participate in DSM. The above means and measures are shown in Table 5.

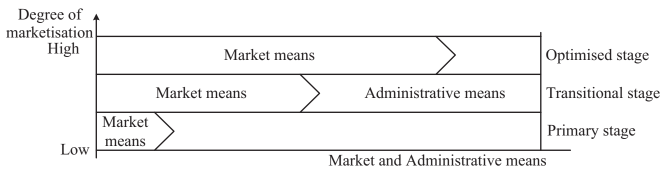



**Fig. 5.** Implementing mode of demand response at different stages [8,28,29].

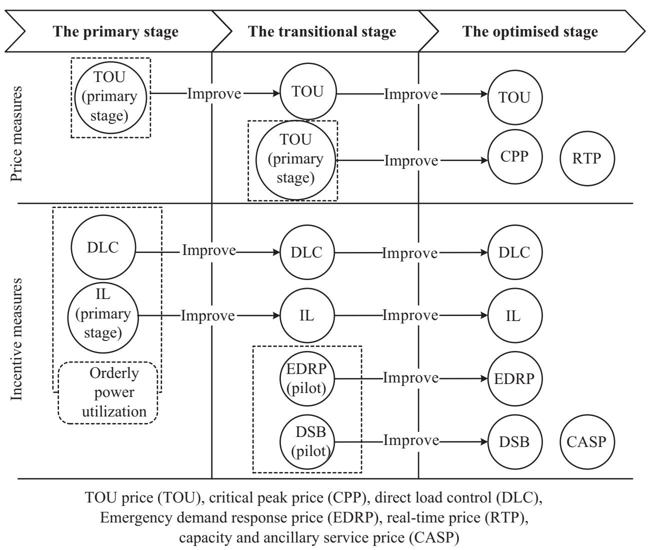



**Fig. 6.** Development path of the demand-side response implementation mode [2,6,30].

Different incentive mechanisms are implemented for different participating subjects [28]. For grid corporations, a bonus and subsidy mechanism is very useful, and a cost-capitalised method and a sales income-separated method are suggested as sound policies. For electricity consumers, it is very important to motivate their interests in participating DSM programs using price mechanisms, such as time-of-use and real-time pricing, and using a contract transaction that can be gradually converted to the bilateral open mode. For energy service companies, part of the DSM special fund can be used as initial capital for an energy service company (ESCO), and providing subsidies is necessary. Additionally, it is helpful to strengthen the credit construction, expand financing channels, and establish and improve the loan guarantee mechanism of ESCO.

### 3.4. Operation mode

DSM programs for energy conservation and emissions reduction have several key procedures for the assessment of the energy conservation potentials, the determination of target market, program promotion, encouragement management, process valuation and program improvement. The implementation procedures are as follows.

- *Energy conservation potentials assessment* [7]: As industrial facilities are different, it is necessary to classify facilities according to their energy consumption status and use similar measures for those facilities with the same status. The project manager is responsible for the analysis work and may hire professionals or trust related departments to perform surveys and data analysis. This work needs the government's acceptance.
- *Target market identification*: Regarding the DSM program or program portfolio, the actual energy conservation potentials is estimated according to the type of facilities and the terminal techniques or system. Capital and personnel can then be distributed in a manner consistent with the energy conservation potentials.

**Table 6**
Costs and benefits of DSM programs for different subjects [5–7,14,26].

| Participating subjects | Costs/benefits |
|---|---|
| Grid corporation | Costs: expense for encouragement and management; revenue reduction for electricity consumption reduction |
| Generation enterprises | Costs: reduced electricity sales and revenue<br>Benefits: reduction in peak-load capacity investment, fuel cost, cost for irregular unit commitment and pollution cost |
| Society | Benefits: reduction in electricity cost; energy conservation and emission reduction |

**Table 7**
The overall benefits of implementing low-carbon power technologies in major energy-consuming industries during the 12th five-year-plan period (2010–2015) [5,9,10,13,30].

| | Industry | Economic potential | | Market potential | |
|---|---|---|---|---|---|
| | | **Accumulative total avoidable power (billion kWh)** | **Accumulative total avoidable installation capacity by 2015 (MW)** | **Accumulative total avoidable power (billion kWh)** | **Accumulative total avoidable installation capacity by 2015 (MW)** |
| Major industrial | Iron and Steel industry | 25.684 | 818.5 | 5.732 | 183.7 |
| | Non-ferrous metals industry | 24.793 | 735.1 | 5.741 | 158.6 |
| | Chemical industry | 42.463 | 1303.2 | 8.523 | 247.5 |
| | Building materials industry | 9.343 | 250.6 | 1.394 | 33.2 |
| | Textile industry | 9.161 | 245.7 | 2.114 | 48.7 |
| | Machinery manufacturing industry | 5.077 | 156.8 | 1.232 | 37.8 |
| | Business | 18.473 | 817.8 | 9.075 | 391.1 |
| | Non-industrial | 12.301 | 464.3 | 4.319 | 201.6 |
| | Residents | 19.003 | 1164.4 | 8.204 | 533.5 |
| | Total | 166.298 | 5956.4 | 46.334 | 1835.6 |

**Table 8**
Programmatic documents [4,5,7–9,11–13,31,33].

| Year | Department | Policy and standard | Related information |
|---|---|---|---|
| 1997 | Central government | Law of the people's republic of China on energy conservation | Formulate financial and price policies |
| 2001 | Former State Economic and Trade Commission | The tenth five-year plan on energy conservation and comprehensive utilization of resources | Develop integrated energy resources planning and DSM |
| 2003 | General Office of the State Council | Notice by the general office of the state council on completing electric power supply | Promote price leverage |
| 2004 | General Office of the State Council | Notice by the general office of the state council on the implementation of resource-conservation program | Optimize electricity production scheduling and focus on energy-intensive industries |
| 2004 | General Office of the State Council | Notice by the general office of the state council on successfully completing electric power supply during the summer | Use effective DSM measures such as load shifting and peak and valley price; Optimize load management and ensure electric power use |
| 2004 | National Development and Reform Committee | The long-term special plan on energy conservation | Develop DSM and comprehensive resources' dispatch |
| 2005 | The state council | Notice by the state council on doing well in recent key work of conservation-oriented society building | Develop supporting and effective incentive policies to promote implement of DSM |
| 2006 | The state council | Decision by the state council on strengthening the energy-conservation work | Optimize power consumption plans of cities and enterprises, promote application of efficient energy saving technology |
| 2007 | The state council | Notice by the state council on distributing the comprehensive implementation plan of energy conservation | Conduct pilot work of efficiency power plant, carry out supporting policies |
| 2007 | The central government | Revision of Law of the people's republic of China on energy conservation | Provide financial and price policies |
| 2008 | General Office of the State Council | Emergency notice by the general office of the state council on strengthening the work of DSM and implementing measures of orderly power utilization | Start the work of orderly power utilization. Try to make power consumption in line with coal supply |
| 2010 | National Development and Reform Committee | DSM approach | Improve peak and valley price and other price mechanism to support application of DSM |
| 2010 | The State Council | Notice on further shutting down low production departments | Shut down low production departments and control redundant construction |
| 2010 | State-owned Assets Supervision and Administration Commission | Interim procedures on supervision and management of energy conservation and emission reduction in central enterprises | Guide and encourage central enterprises to actively implementation energy conservation and emission reduction |
| 2010 | Ministry of Industry and Information Technology, Ministry of Finance, Ministry of Science and Technology | Notice on creating energy-conservation and environment-friendly enterprise | Create energy-conservation and environment-friendly enterprises in resource intensive industries |
| 2010 | Ministry of Industry and Information Technology | Guideline on further enhancing energy-saving and emission-reduction work in small and medium-sized enterprises | Take energy conservation and emission reduction as an important way to develop small and medium-sized enterprises |
| 2010 | The State Council | Notice on making more efforts for the energy-saving and emission-reduction target during the eleventh five-year period(2005–2010) | Improve relevant policies and coordination to guarantee the energy conservation and emission reduction target during the 12th five-year period |
| 2010 | Six ministries including National Development and Reform Committee and science ministry | Technology and policy outline of resource comprehensive utilization in China | Develop resource comprehensive utilizing technology and promote resource comprehensive utilization |
| 2011 | The state council | The integrated plan for energy saving in the 12th five-year plan | Carry out comprehensive pilot work in cities and promote application of efficiency power plant |
| 2011 | The State Council | The 12th five-year plan outline about national economy and social development | Develop resource-saving and environment-friendly production mode and consumption mode |
| 2011 | Ministry of finance and ministry of transportation | Interim procedures of energy-conservation and emission-reduction special fund management in transportation department | Strengthen the management of energy-conservation and emission-reduction special fund in transportation department to increase efficiency |
| 2011 | Ministry of finance and National Development and Reform Committee | Guideline on comprehensive demonstration of energy-conservation and emission-reduction financial policies | Carry out comprehensive demonstration work in some cities with integrated fiscal policies |
| 2011 | National Development and Reform Committee, ministry of finance, ministry of housing and urban– | Guideline on developing natural gas distributed energy | Start up a series of demonstration projects on natural gas distribution energy |

| | | | |
|---|---|---|---|
| | rural development and national energy administration | | |
| 2011 | Ministry of agriculture | Guideline on further strengthening energy-conservation and emission-reduction work in agriculture sector and rural areas | Reduce agricultural pollution, improve rural environment and promote energy conservation and emission reduction in agriculture sector and rural areas |
| 2011 | The state council | The 12th five-year plan of controlling greenhouse gas emissions | Take measures such as optimizing energy structure and increasing energy efficiency to develop industries and life style featured with low carbon |
| 2011 | National energy administration | The 12th five-year plan of national energy science and technology | Make reasonable plans concerning important energy pilot work and determine R&D tasks |
| 2011 | Twelve ministries including national development and reform committee and ministry of education | Implementation plan of energy-conservation and low-carbon work in enterprises | Develop long-run energy-conservation mechanism in some important enterprises and increase energy efficiency |
| 2011 | The state council | The 12th five-year plan of national environment protection | Reduce main pollution and emission and improve public service mechanism to promote environment protection in China |
| 2011 | National development and reform administration | Implementation plan of comprehensive utilization of large solid waste | Improve relevant policies and promote R&D to increase comprehensive utilization efficiency of large solid waste |
| 2011 | National development and reform administration | Guideline on resource comprehensive utilization during the 12th five-year period plan | Explain the major fields for comprehensive utilization of resource, improve policies and increase resource utilization efficiency |
| 2012 | Ministry of commerce | Guideline on energy-conservation and environment-protection demonstration in retail industry | Develop 1000 energy-conservation and environment-friendly enterprises in retail industry during the 12th five-year period |
| 2012 | Seventeen ministries including national development and reform administration and Propaganda department | Implementation plan of social energy conservation and emission reduction during the 12th five-year period plan | Organize 10 special activities concerning energy conservation and emission reduction among communities, teenagers, enterprises, schools etc. |
| 2012 | Ministry of finance and ministry of housing and urban–rural development | Notice on promoting green building development in China | Set relevant standards regarding green building, build incentive mechanism and encourage to construct green buildings in some industries. |
| 2012 | The State Council | The 12th five-year development plan of energy-saving and environment-protection industry during | Explain the major areas and projects in energy-conservation and environment-protection industry and promote its development |
| 2012 | The State Council | The 12th five-year development plan of national strategic emerging industries during the 12th five-year period plan | Explain the development direction and main task of national strategic emerging industries during the 12th five-year period |
| 2012 | The State Council | The 12th five-year plan of energy conservation and emission reduction | Adjust industrial structure, increase energy efficiency and reduce pollution to ensure the accomplishment of energy-conservation and emission-reduction target |

**Table 9**
State special policies and regulations [5,15,19–21,32–36].

| Year | Department | Policy and standard | Related information |
|---|---|---|---|
| 2000 | The former State Economic and Trade Commission and the State Development Planning Commission | Management approaches of power conservation | Implement load management, interruptible load and direct load control |
| 2002 | The former State Economic and Trade Commission | Guideline on the promotion of DSM | Clarify all subjects' responsibilities |
| 2003 | National Development and Reform Committee | Notice on using price to adjust power supply and to promote the rational use of electricity | Promote application of TOU price and encourage plants fully producting and making users shift load themselves. Try out high-reliability price and interruptible price mechanism |
| 2004 | National Development and Reform Committee and the State Electricity Regulatory Commission | Guidance on strengthening DSM work | Ensure standard, effective and sustainable operation of DSM |
| 2010 | National development and reform administration, ministry of finance, People's Bank of China and State Administration of Taxation | Guideline on implementing contract energy management to promote the development of energy-conservation industry | Improve relevant policies and guidelines for energy conservation service industry, and promote the utilization of contract energy management. |
| 2010 | Ministry of finance and national development and reform administration | Interim procedures of financial reward fund management for contract energy management | Explain the supporting objects, supporting measures and supervision of financial reward fund for contract energy management |
| 2010 | General offices of national development and reform administration and Ministry of Finance | Notice on relevant-issue audit and record of energy-conservation service company | Explain the relevant issues concerning the audit and record of energy-conservation service company |
| 2010 | Seven ministries including Ministry of Finance and National Development and Reform Administration | Regulation on CDM fund management in China | Explain detailed rules and regulations for the raising, managing and using of CDM fund in China |
| 2010 | Ministry of Finance and National Development and Reform Administration | Supplementing notice on relevant issues of financial support for the development of contract energy management | Make complementary state on financial support for the development of contract energy management |
| 2011 | Ministry of Industry and Information Technology | Guidance on doing well in the implementation of DSM in industrial areas | Orderly promote DSM in industrial areas |
| 2011 | National Development and Reform Administration | Orderly power utilization management approach | Make plans for the orderly power utilization and provide reasonable subsidy to relevant users |
| 2011 | Ministry of Finance and Ministry of Housing and Urban–rural development | Notice on further promoting public building energy conservation | Strengthen the management of energy conservation in new public buildings, promote the energy-conservation reconstruction in old ones and build relevant supervision mechanism |
| 2011 | Ministry of finance and National Development and Reform Administration | Measures for managing financial reward fund for energy-saving technology improvement | Explain relevant issues concerning the management of financial reward fund for energy-saving technology improvement |
| 2011 | Ministry of finance and National Development and Reform Administration | Notice on further strengthening supervision and inspection of financial-supported contract-energy-management project | Make details on financial-supported contract-energy-management project |
| 2011 | National Development and Reform Administration | Measures for the operation and management of CDM projects | Explain the management mechanism of CDM in China |
| 2011 | General office of the State Council | Notice on launching pilot work of carbon emission permit trading | Approve seven provinces or cities to carry out pilot of carbon emission permit trading |
| 2011 | National Development and Reform Administration | Appraisal program for DSM work in grid enterprises (trial implementation) | Explain relevant issues concerning the appraisal of DSM in grid enterprises |
| 2012 | Ministry of Industry and Information | Guideline on construction of new industrialization industry demonstration base | Provide guideline and fiscal support and improve safeguard measures to promote the construction of new industrialization industry base |
| 2012 | Ministry of Finance, State Administration of Taxation and Ministry of Industry and Information | Notice on energy conservation and the utilization of vehicle and vessel tax for new energy vehicle and vessel | Explain the standard and managing approaches of vehicle and vessel tax for new energy vehicle and vessel |
| 2012 | Ministry of Housing and Urban–rural Development | The 12th five-year special plan of building energy conservation | Improve energy efficiency of new building, expand the energy-conservation reconstruction of old buildings and promote the development of green building. |
| 2012 | Ministry of Finance and National Development and Reform Administration | Interim procedures for central financial reward fund management for DSM pilot work in urban areas | Explain relevant issues concerning the management of financial reward fund management for DSM pilot work in urban areas |
| 2012 | National Development and Reform Administration | Appraisal program for enterprises' energy conservation | Explain the appraisal mechanism for enterprises' energy conservation |

- *Program promotion*: Various marketing strategies are required to convince decision makers to adopt the DSM programs. In program promotion, different measures, such as technical training, documents distribution and special program induction, is supposed to be used for different objects [29].
- *Incentive management*: Once implemented, DSM programs focus on specific operation management. The basic unit of the programs is project engineering, so the program management portfolio is used to address items such as incentive payments and choosing the timing and terms of payment.
- *Process valuation and program improvement* [24]: Continuous assessment of the DSM's situation is required. Improvement for the program structure is indicated to be based on the assessment result to increase the overall benefits. Even a simple internal audit can help to correct the mistakes in implementation.

Many more instruments are required to strengthen and deepen the DSM programs. The terminal energy consumption mode is the focus, and DSM programs are conducted based on economic incentives, that is, demand response programs. Various demand response measures are relied on to motivate users to change their usual power consumption behavior, thus reducing peak load, improving system reliability and energy efficiency and reducing overall costs. Based on the different administrative and market instruments, the implementation mode of demand response under different monetization degree can be divided into three types: the initial stage, the transition stage and optimized stage (Fig. 5).

Fig. 6 shows the development path of the demand-side response implementation mode, considering the application and development of specific measures, such as time of use price, critical peak price, real-time price, direct load control, interruptible load, emergency demand response and demand side bide.

### 3.5. Results assessment

Implementation of the DSM will not only result in direct energy conservation, such as electric power saving and load reduction, but will also have direct and indirect economic influence on related subjects. A successful DSM program should involve all participating subjects and benefit them as well. Additionally, the pre-assessment and post-assessment of DSM should consider economic benefits of related subjects. The quantitative estimation of benefits is suggested to provide support for subjects to make decisions on DSM. The costs and benefits are shown in Table 6.

The developing scale of demand-side low-carbon power technology could be obtained by calculating its energy saving potential [31]. The energy saving potential of demand side refers to energy that could be saved by end users, mainly including saved power and saved installation. It is commonly known as energy saving potential because of its potential awaiting discovery.

The quantity of demand side energy saving resources is different depending on different standards. Generally, energy saving potential could be classified into technical potential, economic potential and market potential. Normally, market potential is less than economic potential, which is less than technical potential as well. DSM planning emphasizes on economic potential and market potential, namely cost-effective energy-saving resources and available energy-saving resources. The overall benefits of implementing low-carbon power technologies in major energy-consuming industries during the 12th five-year-plan period (2010–2015) is obtained through estimation of the developing scale of demand-side low-carbon power technology, which is shown in Table 7.

As Table 7 shows, during the 12th five-year-plan period (2010–2015), the accumulative energy-saving potential of implementing DSM technologies in major power-consuming industries is great. As for market potential, the accumulative total to-be saved power during the 12th five-year-plan period (2010–2015) could achieve 46.334 billion kWh, while accumulative total to-be saved installation capacity by 2015, 1835.6 MW.

## 4. Incentives

### 4.1. Policies and regulations

The related programmatic documents and state-specific policies and regulations about DSM are shown in Tables 8 and 9.

Local governments must also implement measures concerning DSM projects. For example, Hebei province established a DSM special fund in 2002. Since 2003, Jiangsu government has shouldered 1/3 (approximately 40 million) of the burden of enterprises and implemented the supporting policies and measures of DSM projects. Jiangxi and Shanxi have established a DSM special fund from an urban construction surcharge. Fujian and Shanghai have also established DSM special funds [37].

In summary, the policies and regulations in Tables 8 and 9 indicate that the government has been consistently promoting the development of DSM programs, and DSM now has become an important type of energy resource to achieve the goal of energy conservation and emissions reduction. This success has occurred because the implementing subjects are clearer, and various measures including economic, technological, legal and administrative measures, such as season price, high-reliability price, interruptible load price, equipment energy efficiency, have been implemented, and the electricity user's concerns are considered as well. Based on the existing polices, it is suggested that the relevant departments should further enact polices concerning supervision mechanisms to assess and evaluate the DSM programs by implementing results regularly to realize their potential benefits.

### 4.2. Recommendations

(1) *Establish a DSM organization system suitable for China's national conditions to promote DSM*: The government should initiate a DSM leading group with the DSM office under its control and group it with a committee of experts. Relevant laws and policies should be launched to authorize the related grid corporations to be the implementation subjects and urge them to perform DSM projects with energy service companies under the guidance, participation and supervision of the committee of experts, who are responsible for selecting, supervising, and testing DSM [38].

(2) *Formulate relevant policies and regulations to encourage DSM's participants*: The government should ensure DSM's important status and the grid corporations should regard DSM as a type of resource and integrate it into the electric power industry development planning, energy development planning and regional economic development planning. Gradually improve the assessment and supervision of DSM and rigorously check the energy efficiency standards of electrical equipment. Promote the involvement of all parties by deepening the existing mechanisms and introducing new incentive mechanisms.

(3) *Perform a scientific and rational price mechanism to create a good environment for the effective operation of DSM* [39]: Gradually increase the price level of living electricity while implementing the cascade tariffs, simultaneously provide subsidies to poor residents, and make full use of the price factor in the construction of a conservation-oriented society, so that energy has a greater market space, thus contributing to the effective operation of DSM.

(4) *Develop reasonable and effective financing mechanisms and fund the operation mechanism to promote the orderly operation of DSM*: The government could take a fraction of the annual increase of the fiscal revenue as a source of long-term and

stable financing for DSM. Extracting funds from the electricity tariffs, issuing treasury bonds, fighting for the support of other energy-saving or environment funds and sharing energy efficiency could be considered to increase the funds for DSM. A DSM special fund could be used to provide subsidies, low-interest loans and loan guarantees or to provide access to capital markets, thus establishing a closed-loop management process of capital flow [40]. Power enterprises should take the initiative in the market to find the financing channels of energy-saving funds, making multiple-channels financing in the financial markets, the energy-saving technology and equipment market and the international markets.

(5) *Establish a DSM supervision organization to effectively assess DSM*: We should develop the DSM program decision-making mechanism and accountability system by establishing a DSM supervision group who provides a platform for information exchange with power users and discloses the implementation of the DSM programs. Additionally, the DSM supervision group should establish a DSM project evaluation panel of experts who could provide an effective and objective assessment of DSM implementation with the established comprehensive and scientific evaluation index system and routinely provide feed-back information and a summary.

(6) *Implement the energy contract management mechanism to actively cultivate the energy services market*: China's current energy contract management is still in the primary stage, but if we learn from the tradable certificate mode and let energy service companies participate in the certificate market, we will not only achieve energy conservation goals but also greatly expand the development space of energy service companies and promote the development of energy service companies [6].

(7) *Rely on the development of the smart grid to accelerate the research and application of various DSM hardware technologies and promote pilot programs*: Increase efforts to promote and apply load management techniques, expand the installation range and load control range, and establish the DSM information network and management information system. Constantly improve the implementation of DSM using feedback from users. When the pilot project comes to an end, have the experts to provide a comprehensive assessment of the pilot projects, rank the projects in accordance with their implementation and introduce a phased project promotion plan.


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